Habitable Zones

DESCRIPTION
Students explore some of the reasons to think extraterrestrial life is possible by varying the distance from the Sun, studying organisms living under extreme conditions on Earth, and investigating extreme temperature effects on metabolism.

OBJECTIVES
Students will
- Experiment with gas production of yeast at different temperatures
- Take, record, and plot data from an experiment
- Discuss extreme temperature environments on Earth and Mars
- Observe the relationship between temperature and metabolism
- Explore the effect of distance from the Sun on a planet's average surface temperature
- Extract key information from a reading
- Draw conclusions and make inferences when creating sets
- Understand extremophiles as analogs for extraterrestrial life
- Debate the ethics of sending Earth life to another world

NATIONAL STANDARDS

National Science Education Standards
Science as Inquiry
- Understanding of scientific concepts
- Skills necessary to become independent inquirers about the natural world
- The dispositions to use the skills, abilities, and attitudes associated with science

Life Science
- Organisms and environments
- Structure and function in living systems
- Diversity and adaptations of organisms

Earth and Space Science
- Structure of the earth system
- Earth in the solar system

Science in Personal and Social Perspectives
- Types of resources
- Changes in environments
- Populations, resources, and environments
- Risks and benefits

ISTE NETS and Performance Indicators for Students
- Use models and simulations to explore complex systems and issues
- Locate, organize, analyze, evaluate, synthesize, and ethically use information from a variety of sources and media

MANAGEMENT
The lesson activities are extracted from three educational resources:

NASA JSC Astrobiology: Fingerprints of Life
It's Just Right, pp. 1 – 5
http://solarsystem.nasa.gov/docs/Its_Just_Right.pdf

Astrobiology in your classroom: Life on Earth … and elsewhere?
Activity 4: What can life tolerate? pp. 37 – 48
http://nai.arc.nasa.gov/library/downloads/ERG.pdf

The Sun's Habitable Zone
Life in Space: Part 2 Build Your Own Planet
Planet Temperature Calculator
http://www.astro.indiana.edu/~gsimonel/build.html

For activity 1, determine the number of groups (based on four to a group) and assemble appropriate equipment and materials. The basin needs to be large enough to hold one container from each team. The chart included in the lesson plan details the amount of each ingredient.

For activity 2, the teacher will need to copy one activity guide for each student and one set of *Life on the Edge* cards for each student group of four.

For activity 3, a computer with Internet connection will be required so that each student or team of students can build a planet and, using the variables of the mass of the star the planet it is orbiting, the distance of the planet from the star, the bond albedo of the planet, and the greenhouse effect of the planet's atmosphere, be able to see if their planets can sustain life.

MATERIALS

Activity 1 (per group)
- Four 0.5-L or smaller clear beverage containers Note: all bottles need to be the same size and shape
- Four 20- to 25-m balloons (8 to 10 inch)
- Two packages of dry baker's yeast or equivalent
- Warm tap water
- Basin filled with warm water
- Three thermometers
- 40 ml sugar (1/4 cup)
- Two measuring spoons
- Measuring cups
- Two to four magnifying lenses
- Metric rulers

Activity 2
- One Activity Guide (pp. 41 – 42) for each student
- One set of *Life on the Edge* cards (pp. 46 – 48) per four students
- Poster materials

Activity 3
- Internet connection to allow for each student or student group to build a planet

CONTENT RESEARCH
Metabolism refers to the physical and chemical processes that make energy available to an organism. Metabolism is affected by temperature: the colder the temperature, the slower the reaction rate. When the rate of these life-sustaining reactions drops beneath a critical level, the organism will die.

For the "It's Just Right" activity, one-celled organisms commonly known as baker's yeast will be studied. When placed in warm water, the cells activate. As the metabolism awakens, the cells generate carbon dioxide gas. By observing the presence of this gas, the students will be able to make inferences about metabolism.

Extremophiles live at the limits of what life's chemistry is able to tolerate. If organisms on Earth can thrive under such conditions, then one might reasonably expect that similar conditions on other worlds might support life as well.

Key Concepts:
- We must base any search for extraterrestrial life on what we know about life on Earth.
- Extemophiles live at the limits of what life's chemistry is able to tolerate.
- Any place that mirrors Earth's life-sustaining environments may harbor life.
- As we explore the solar system, we find evidence for conditions that may support life.
- If extraterrestrial life is found in our solar system, it will most likely be microbial and inhabit environments considered extreme on Earth.
- To date, no extraterrestrial life has been found in the solar system.

Key Terms:

- **Metabolism:** the chemical processes occurring within a living cell or organism that are necessary for the maintenance of life
- **Microbe:** a very tiny form of life
- **Extremophiles:** an organism that has adapted to living in conditions of extreme temperature, pressure, or chemical concentration
- **Albedo:** the ratio of light reflected by a planet or satellite to that received by it

LESSON ACTIVITIES

NASA JSC Astrobiology: Fingerprints of Life
It's Just Right, pp. 1 – 5
http://solarsystem.nasa.gov/docs/Its_Just_Right.pdf
Students will put granules of yeast and sugar into containers. By varying the temperature of the water added and recording the amount of gas as demonstrated by the balloon inflation diameters, the students observe the relationship between temperature and metabolism.

Astrobiology in your classroom: Life on Earth … and elsewhere?
Activity 4: What can life tolerate? pp. 37 – 48
http://nai.arc.nasa.gov/library/downloads/ERG.pdf
Students read about extremophiles, answer questions, and then play the card game reinforcing the concepts presented.

The Sun's Habitable Zone
Life in Space: Part 2 Build Your Own Planet
Planet Temperature Calculator
http://www.astro.indiana.edu/~gsimonel/build.html
This Web site provides a way for students to build a planet by changing the variables. Each planet received a rating of cold, hot, or habitable based on the data entered by the students. Four characteristics are used: the mass of the star the planet is orbiting, the distance of the planet from the star, the bond albedo of the planet, and the greenhouse effect of the planet's atmosphere.

ADDITIONAL RESOURCES

Astro-Venture's Biology Training Module
This module guides you, as a Junior Biologist, through your job to change the biologic features of Earth and observe the effects. You will also explore how these features work together to help make a planet habitable to humans.
http://astroventure.arc.nasa.gov/biology/training

Examples of Earthly Extremophiles Poster
This poster contains images of extremophiles in cold, hot, deep-underground, bottom-of-the-sea, and high-acidity environments.
http://nai.arc.nasa.gov/poster/poster_images/astrobioactivity1-studenthandout.pdf

NASA Minute Now
NASA scientists discuss how scientists study microbes that live in Earth's extreme environments.
http://www.youtube.com/watch?v=cf3i8jsUqtc

NASA Center for Mars Exploration
This site on exobiology discusses Mars exploration and the search for life on Mars.
http://cmex.ihmc.us/CMEX/data/SiteCat/sitecat2/exobiolo.htm

DISCUSSION QUESTIONS

- Where can we find life on Earth in unexpected places? *Answers will vary—poles, depths of the ocean, volcanoes, and caverns*
- Why are the life forms that live in these extreme environments so tiny? *With fewer parts and fewer internal processes to coordinate, less can go wrong*
- If organisms on Earth can thrive under extreme conditions, then couldn't organisms live under similar conditions on other worlds? *Most likely*
- Should scientists send microbial life to another world to see if they would survive? *Answers will vary*
- How did the width of the balloon change with the temperature of the water? *Have students present their data charts and graphs*

ASSESSMENT ACTIVITIES

- Observe and assess student performance throughout the activities.
- Evaluate the activity log sheets for the first two activities.
- Have the students demonstrate the game *Life on the Edge.*
- Have the students demonstrate the building of a planet capable of supporting life by using the planet temperature calculator online.
- Student teams should be able to explain metabolism and the relationship to temperature, explain what a "habitable zone" is, and articulate that microbial life (and possibly extremophiles) would be the most likely candidate for extraterrestrial life.

ENRICHMENT

- Research planets that have recently been identified. Are there any that would be considered "habitable"? How rare is Earth? Have student teams debate this question. Be sure that scientific information is central to the debates.
- Have teams of two students develop a set of planet characteristics that may support life. Then each team delivers the criteria to a microbe team that designs a microbe that could exist on that planet.
- Set up debate teams to provide the pros and cons of sending microbial life to another world.
- Assign a microbe from the list of "champions" on page 41 of the "What can life tolerate?" activity to each student team. Each team should present a report on their assigned "champion." Where else could they send the champion and have it survive?